Are Anxiety and Fear Separable Emotions in Driving? A Laboratory Study of Behavioural and Physiological Responses to Different Driving Environments.

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1. Abstract

Research into anxiety and driving has indicated that those higher in anxiety are potentially more dangerous on the roads. However, simulator findings suggest that conclusions are mixed at best. It is possible that anxiety is becoming confused with fear, which has a focus on more clearly defined sources of threat from the environment, as opposed to the internal, thought-related process associated with anxiety. This research aimed to measure feelings of fear, as well as physiological and attentional reactions to increasing levels of accident risk. Trait anxiety was also measured to see if it interacted with levels of risk or its associated reactions. Participants watched videos of driving scenarios with varying levels of accident risk and had to rate how much fear they would feel if they were the driver of the car, whilst skin conductance, heart rate, and eye movements were recorded. Analysis of the data suggested that perceptions of fear increased with increasing levels of accident risk, and skin conductance reflected this pattern. Eye movements, when considered alongside reaction times, indicated different patterns of performance according to different dangerous situations. These effects were independent of trait anxiety, which was only associated with higher rates of disliking driving and use of maladaptive coping mechanisms on questionnaires. It is concluded that these results could provide useful evidence in support for training-based programs; it may also be beneficial to study trait anxiety within a more immersive driving environment and on a larger scale.

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2. Introduction

It has become increasingly apparent in recent studies that emotions can have a subsequent impact on driving behaviours (Pêcher, Lemercier & Cellier., 2009; Trick, Brandigampola & Enns, 2012). However, some research has gone into more detail and looked at how negative emotions can influence driving; as a result we are now aware that trait characteristics are important when considering negative behaviours such as aggressive driving (Stephens & Sullman, 2014), as they could result in increased acceleration and increase steering wheel use, as indicated by an increase in standard deviation (Stephens & Groeger, 2009).

Yet it is the relationship between anxiety and driving that has gained increasing interest. Anxiety is a feeling of tension or unease at the prospect of a threatening, but not guaranteed event, and can take form in a person's state or trait (Rachmann, 2013). There are two ways that anxiety can have an impact on driving. Firstly, it can result in a restriction of behaviour that may result in maladaptive consequences. Higher levels of anxiety are generally positively correlated with a higher frequency of, and preferences for, low self-paced activities such as housework and reading, as opposed to driving (Moller & Siguroardottir, 2009). This may be due to the fact that anxiety can lead to preoccupying and dysfunctional thoughts (da Costa et al., 2014) such as the risk of mortality (Ben-Ari, Florian & Mikulincer, 2000). As a result this may reduce the desire to drive, therefore reducing the mobility and independence of the driver (Taylor, Alpass, Stephens & Towers, 2011). In normal populations people prefer driving to public transport regardless of financial cost (Innocenti, Lattarulo & Pazienza, 2013), possibly due to a need to maintain a high level of social and psychological well-being

(Stanley & Stanley, 2007; Vella-Brodrick & Stanley, 2013). If this is the case then it is important for research to clarify if anxiety subsequently influences driving behaviour, or if there is any relationship between anxiety and risk of accident.

This leads on to the second way in which anxiety, specifically trait anxiety, may negatively impact driving. Based on questionnaire data it has been suggested that those who are high in trait anxiety are more prone to showing signs of dangerous driving behaviours. A study conducted by Ulleberg (2003) identified six subtypes of driver; one of these subtypes, characterised by high levels of sensation-seeking, aggression and anxiety, was suggested to be a risky driving group. Many questionnaire-based studies have since provided support for this theory. A positive correlation has been found between trait anxiety and mistakes on the road (Panayiotou, 2015), as well as between trait anxiety and the Driver Behaviour Questionnaire (Pourabdian & Azmoon, 2013; Shahar, 2009). The fact that the Driver Behaviour Questionnaire measures the amount of errors, lapses and violations indicates that higher trait anxiety could make a driver more dangerous on the road. A recent questionnaire study suggested that those with higher levels of anxiety caused more accidents, and were responsible for dangerous behaviours such as tailgating and driving under the influence (DUI) (Dula, Adams, Miesner & Leonard, 2010). Recently released statistics by the UK's Department of Transport reveal that in 2013, tailgating and DUI episodes contributed to over 12,000 accidents, 16 and 159 of which were fatalities for each behaviour respectively (Department for Transport, 2014). If anxiety is contributing to such behaviours then it is clear that more research needs to focus on the relationship between anxiety and dangerous driving.

However, it is important to note that questionnaires alone are dependent on self-report, and may not necessarily reflect real-life driving behaviours. A well as this, some questionnaire studies provide little or conflicting evidence to support the idea that anxiety is related to dangerous driving. For example, some studies suggest that anxiety has little (Oltedal & Rundmo, 2006) or no (Nordfjaern, Jorgensen & Rundmo, 2012) influence on dangerous or risky driving. Others have even suggested that those high in anxiety may aim to alleviate these feelings by adopting safety conscious behaviours such as speed reduction and increased distance from vehicles in front (Clapp et al., 2011), which contrasts to other questionnaires that suggest anxiety contributes to increased speeding (Roidl, Frehse & Hoeger , 2014) and tailgating (Dula et al., 2010). Therefore it may be more important to measure variables in alternative paradigms, such as laboratory and simulator-based studies. In particular, it has been recommended that research into anxiety and driving should examine more objective variables such as physiological and behavioural measures (Dula et al., 2010).

Findings on both physiological and behavioural measures indicate that there is some evidence that anxiety may be detrimental to driving. Simulator research has found that those higher in anxiety are worse at detecting specific signs amidst other distractors, and may take longer to brake at pedestrian crossings (Morton & White, 2013). When discussing a fearful topic whilst driving, those higher in state anxiety also show evidence of visual tunnelling (Briggs, Hole & Land, 2011), in a similar fashion to what is seen when participants are faced with dangerous situations (Chapman & Underwood, 1998). Whilst this may reflect an attempt to direct attention to a potential source of threat as a result of anxiety (Ohman, Flykt & Esteves, 2001), this may not necessarily be advantageous behaviour in the real world. In support of this idea, real-road research has also suggested that higher anxiety can result in a greater number of errors on the road (Taylor, Deane & Podd, 2007), and that high state anxiety can lead to a greater likelihood of failing the British Driving Test; this latter finding was also associated with a significant increase in heart rate (Fairclough, Tattersall & Houston, 2006). These findings may imply that high anxiety could make someone not safe enough to drive on the roads.

It is also worth noting, however, that other simulator research has produced mixed findings. In a recent simulator study looking at a wide range of emotions and their impact on subjective risk, workload and driving performance, anxiety was found to increase levels of subjective risk, but did not result in a statistically greater amount of driving errors compared to controls (Jeon, Walker & Yim, 2014). As well as this, there are other practical reasons why anxiety effects have been found in previous research. For example, in Fairclough et al.'s (2006) study, the presence of an additional tester in the car with the participant is unusual for the British Driving Test, and thus could have elevated heart rate. In Briggs et al.'s (2011) study, the fact that a conversation was taking place could have led to differences in attention. Other research has already suggested that holding conversations can have negative effects on attention (Amado & Ulupinar, 2005) and situational awareness (Heenan, Herdman, Brown & Robert, 2014).

Taking these findings into consideration, it is not surprising that some researchers believe that emotions such as anxiety only have a minor influence on driving behaviours (Sjoberg, 2006). However, one possible reason for these inconclusive findings is that anxiety may be confused in the literature with another emotion, fear (Dula & Geller, 2003). For example, in Jeon et al's (2014) paper, they interchange the terms 'anxiety' and 'fearful'. In fact, whilst both signal the presence of threat, fear arises as the result of known environmental sources whereas anxiety can be objectless with little probability of threat occurring (Rachmann, 2013).

Research conducted into the studies of physical and social fear highlights that fear of physical danger is best predicted by threat and the likelihood of its outcome (Rapee, 1997). This could suggest that fear of physical danger within the driving environment could thus be predicted by the degree to which a driver is involved in a situation that increase the likelihood of injury or death. This has been acknowledged within the driving research, where it is claimed that fear can depend on external demands (Schmidt-Daffy, 2012; Schmidt-Daffy, 2013). Thus by worsening visibility in fixed-speed computer-based drives, feelings of threat and skin conductance responses can increase(Schmidt-Daffy, 2013).

This concern about the distinction between fear and anxiety has been made apparent with the driving literature (Taylor, Deane & Podd, 2008), and research has suggested within the driving context that people perceive driving anxiety and driving fear as similar concepts (Taylor & Paki, 2008). Yet the differences between the two are important for two reasons. Firstly, emotions of the same valence have been shown to produce different responses. Research into emotions and risk perception has suggested that fear and anger are positively and negatively related to perceived risk respectively (Lerner & Keltner, 2000), and differences in decision making are also found between sadness and disgust (Lerner, Small & Loewenstein, 2004). Secondly, the difference between anxiety and fear suggests that the former is based on top-down, internal influences and the latter is based on environmental influences. The transactional model of stress suggests that the person and the environment interact to produce a stress response (Lazarus & Folkman, 1984). Thus it is possible that fear and anxiety interact to produce differential responses within the driving environment, or that anxiety may modulate the degree to which responses are made within different driving environments.

Based on the fundamental difference between the two emotions with respect to the presence of threat, it is possible to suggest that fear and anxiety manifest as a result of bottom-up and top-down cognitive influences respectively. Schmidt-Daffy's (2013) research could provide some empirical evidence for this suggestion. In Schmidt-Daffy's paper, it was acknowledged that the symptoms of the two emotions are difficult to distinguish and often occur at the same time, in varying proportions. However, it was suggested that whilst fear arises due to task demands, such as those determined by environmental factors, anxiety may manifest as a result of motivational demands. In a computer-based study, participants had to drive using the 'space' bar on a keyboard, and in some trials they had to brake at the presence of a silhouette of a deer. Environmental demands were manipulated by increasing or decreasing visibility of the road leading towards the hazard, and anxiety was manipulated by incurring different levels of monetary penalty if the deer was hit or the drive was not completed fast enough. The magnitude of monetary penalty was said to result in low, medium or high internal conflict. Findings suggested that the different manipulations resulted in increases in self-reported anxiety and physiological reactions depending on the type of task. For example, lower road visibility only resulted in increases in subjective anxiety when speed was fixed, whereas conflict only resulted in increases in subjective anxiety in self-paced driving.

Schmidt-Daffy's study is a good attempt to distinguish between the two emotions, and provides some interesting implications for how they differentially impact both driving behaviours and physiological reactions. However it is difficult to say whether it has good ecological validity; the computer display itself had a simple road on a grey background to symbolise the environment, and a silhouette of a deer was used rather than a detailed depiction of one. It is important to assess whether similar evidence is found within more realistic depictions of driving environments. It may also be important, in terms of road safety implications, to investigate anxiety in terms of personality; it is within this context that studies have suggested anxiety makes a driver more dangerous (Dula et al., 2010; Panayiotou, 2015; Shahar, 2009).

Therefore, the aim of the present study was to assess how participants with differing levels of trait anxiety respond to differing levels of threat within videos of genuine driving environments. On this basis, videos of driving videos represent the definite, external threat that may be theoretically interpreted as fear whilst the more objectless aspect of threat is evident in trait anxiety. Trait, rather than state, was chosen on the basis that the majority of driving research has found significant differences with trait rather than state anxiety (Pourabdian & Azmoon, 2013; Moller & Siguroardottir, 2009). There were two key questions being investigated. Firstly, can real driving videos with increasing levels of threat affect subjective, physiological and attentional fear responses? Secondly, can these responses be affected by different levels of trait anxiety? In a similar methodology to one that has already been used within previous research (Charlton, Starkey, Perrone & Isler, 2014; Pelz & Krupat, 1974), participants were required to watch videos of driving scenarios, imagining they were the driver of the car, and continuously rate how much fear they would feel in the given scenario, whilst physiological and attentional variables were measured. Based on the previous literature it was predicted that with increasing levels of threat within the driving videos, increasing levels of fear would be experienced by the participants, and physiological and attentional variables may reflect these increases in fear. However, it was also predicted, without specific direction, that different levels of trait anxiety could have differential impacts on these responses. This would potentially imply differential impacts of top-down and bottom-up influences of the two emotions on driving-related feelings.

3. Methods

3.1 Participants

Fifty-seven participants were recruited for this study, and ranged in age between 18-42 years (mean=22.75; SD= 4.54). Forty-one were female and sixteen were male. They were all either students or employees from the University of Nottingham, who were recruited using a poster advertisement, and they were compensated with an inconvenience allowance at the end of the study. All participants held a full driver's licence; on average, they had been in possession of these for 4.6 years and drove a self-reported average of 6930 miles per year. Fifteen had been in a minor road accident in the past three years, one had been in a major road accident and one had been convicted of driving offences. Ethical approval was obtained from the University of Nottingham's Ethics Committee prior to commencing testing, and participants signed a consent form prior to participation stating their willingness to take part. To minimise distress levels, prospective participants were advised not to volunteer if they had a history of anxiety disorder.

After the experiment had been completed, participants were also made aware of potential risks to driving after completing a study, and they signed a post-trial consent form stating that they had received this information and were willing to not drive immediately after completing the experiment.

3.2 Design

This study had a mixed-design including two within-subjects factors and one continuous variable. The continuous variable was the level of trait anxiety expressed by the participant. The first within-subjects variable was the level of environmental arousal shown in the driving clips, all of which were taken from the driver's point of view. Environmental arousal was manipulated using three types of clip so this variable had three levels (uneventful, hazardous, and crash). In the lowest level of arousal, a car would be driving down a road and no negative events would occur (uneventful). In other words, no incidents would occur that would require the participant's car to brake or take any action to avoid a car accident, nor did any incidents on the road result in a subsequent accident. These clips were chosen by the researchers after careful observation and ensuring that the uneventful clips fulfilled these criteria. Clips with moderate levels of arousal (hazardous) were practice Hazard Perception clips provided by the UK's Driving Standards Agency (DSA); in DSA-created Hazard Perception clips, a car drives along a road, and an event happens that would normally require the driver to stop or take evasive action to avoid a crash. Clips with high levels of arousal included an actual collision involving the driver's vehicle (crash). For ethical purposes none of these crash clips contained any fatalities or evidence of visual harm to vulnerable groups such as people and animals. In the hazardous and crash clips, only one key event was shown per clip, so in the former only one hazard occurred and in the latter only one crash occurred. Six clips were shown in total for each level of environmental arousal, giving a total of eighteen clips. To allow us to control for effects of clip time (as video clips of crashes were significantly shorter than Hazard Perception clips ($t(10)=8.514, p<.0001$)), half of the uneventful clips matched the average length of time of hazardous clips and the other half matched the average length of time for crash clips (a table containing timings for all video clips, plus descriptions of each clip, can be found in Appendix 'A'). Clip order was also counterbalanced across participants.

In order to observe how variables were affected across time, the second within-subjects variable was the time window in which measurements were taken, and there were three levels of this (control, precursor, and outcome): a 'precursor' window measured between the onset of a hazard or crash, until the event occurred, a 'control' window before this (the period of time from the start of the clip until the beginning of the precursor window) and an 'outcome' window (the period of time from the end of precursor window until the end of the video clip). Clips provided by the DSA already contain defined precursor windows that mark the start and end of each hazard. The onset of a hazard is defined as the moment the stimulus that causes the subsequent hazard appears on screen and in the actual hazard perception test no responses earlier than this count as successful detection of the hazard. The end of a hazard is defined as the point at which the hazard has fully developed and is occurring. Responses any later than this do not gain candidates any points in the test. For compatibility with other research on hazard perception we have used exactly the hazard windows defined by the DSA. Using these same criteria, for crash clips, the precursor window began on the first appearance of the vehicle that eventually results in the crash, and ended at the point of impact between cars. To create comparable windows for uneventful clips, these windows were matched for time by taking the average start and end frame of hazardous and crash clips, and using these as windows for the safe clips that were the same length as the hazardous and crash clips respectively.

Dependent variables included mean perceptions of fear made on a variable response transducer (VRT) measured on a scale between 0 and 9, as well as reaction times to respond to the event. Rather than using discrete hazard perception button presses, responses in the current study were coded as the time at which there was a distinct upturn in the VRT trace (Pelz & Krupat, 1974). To control for length of measurement window, these reaction times were standardised by converting them into hazard perception scores after data extraction (for a diagram describing how this was calculated, plus a diagram of the experimental design, see Figure 1). For precursor windows in hazardous clips this measure is equivalent to the score participants would obtain if they were doing an actual hazard perception test. In all other conditions it provides a measure that combines how likely the participant was to respond, with how soon in the window the response was made.

As a large amount of literature suggests that variables such as skin conductance (Williams et al., 2006), heart rate (Murakami, Matsunaga & Ohira, 2010) and eye movements (Kimble et al., 2014; Rachmann, 2013) are linked to anxiety and fear, a series of physiological and attentional variables were also measured. This included mean skin conductance (in microSiemens), mean heart rate (in BPM) and saccadic amplitude (in degrees).

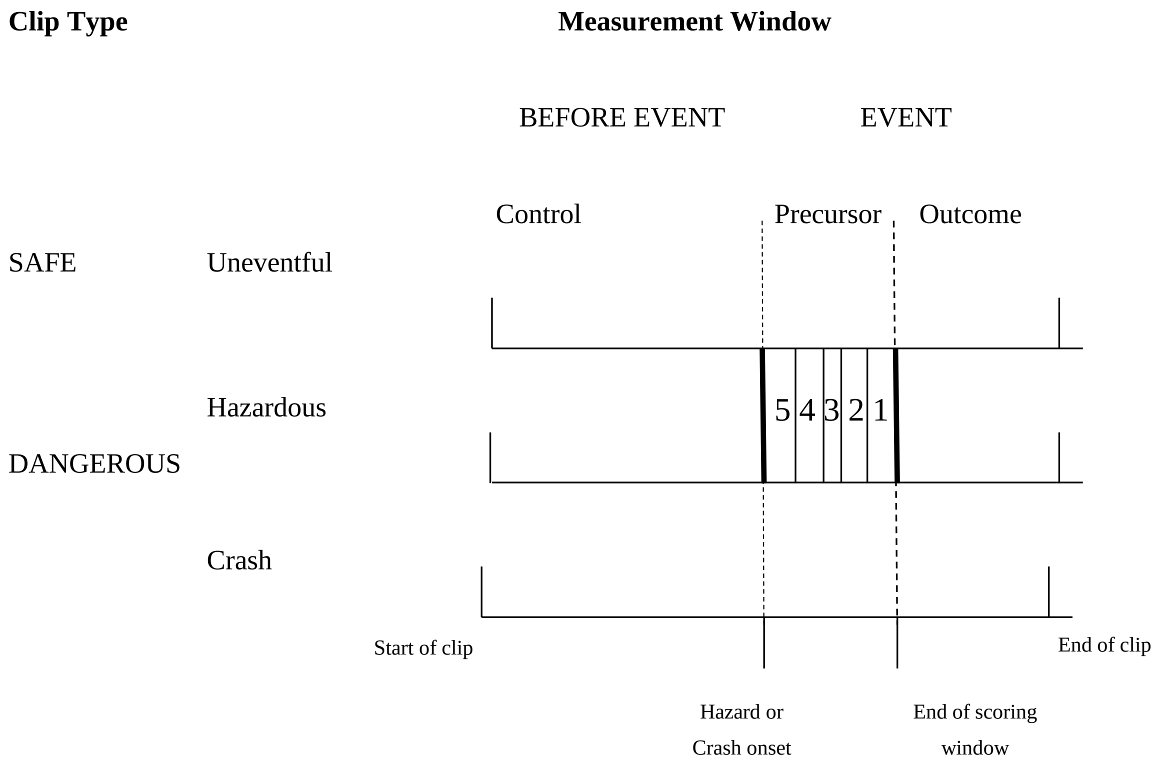

Figure 1: Diagram of the study’s design. This shows the types of safe (uneventful) and dangerous (hazardous or crash) clips that were shown to participants, along with the types of windows (control, precursor or outcome) that measurements were taken in. Scores were calculated for each precursor window; scores of either 5,4,3,2 or 1 were given according to whether the participant made a response up to 20,40,60,80 or 100% of the way into the window respectively; any responses made after this window, or no responses at all, obtained a score of 0. These criterion are based on those used in the UK Driving Standards Agency’s Hazard Perception Test.

3.3 Materials and Stimuli

3.3.1 State Trait Anxiety Inventory

The State-Trait Anxiety Inventory (STAI) was used to measure anxiety (Spielberger, 1983). Both parts consist of 20 items that are rated on a 4 point Likert scale. Questions regarding state (Y1) ask the participant how they are feeling ‘right now’, with responses ranging from ‘not at all’ (1) to ‘very much’ (4), whilst trait related questions (Y2) ask how the participant ‘generally’ feels, with responses ranging from ‘almost never’ (1) to ‘almost always’ (4). On each part of the questionnaire, participants can gain a minimum score of 20 and a maximum score of 80. In the present study, the average trait score was 37.65 (*sd* =7.72) and reliability of the trait aspect of the questionnaire was high in the present study (Cronbach’s α=.894).

3.3.2 Other Stimuli

Stimuli consisted of nine hazard perception video clips obtained from the DSA, and nine videos obtained from various internet sources. Three of the DSA video clips and three of the internet clips were edited to show uneventful driving; of these six newly edited clips, three were matched for average time length for the Hazard Perception Clips and three were matched for average length of the car accident clips. Due to the fact that Hazard Perception clips did not contain any audio, sound was removed from all clips to remove possibility of this becoming a confound. The eighteen clips were then edited into one video using Final Cut Pro, according to three counterbalanced random orders. Two seconds prior to viewing each clip participants would see message saying ‘Clip ‘X’’ written in white Arial font on a black background, with ‘X’ representing the appropriate clip number. After these videos had been created they were then recorded onto Sony MiniDV video cassettes using a Sony digital video recorder.

Stimuli were then played back onto an 18 inch Sony monitor via a Sony DVCam. To track eye movements, a fixed head & chin rest was placed approximately 60cm away from the Sony monitor, and eye movements were tracked using a SensoMotoric Instruments IView X RED eye tracker. The tracker had a sampling rate of 50 Hz and a spatial resolution better than 0.5 degrees. Eye movement calibration was enabled using WinCAL and IViewX software, both of which were operated using separate computers. Perceptions of fear were measured using a Biopac variable response transducer (TSD115), and galvanic skin response was measured on the non-dominant hand using two finger straps attached to the ring and little fingers, with the finger straps filled with isotonic gel (GEL101, Biopac Systems Inc., Goleta, CA, USA). Heart rate was measured using Cnap Monitor 500; prior to experimentation the participants were fitted with appropriately sized arm and finger cuffs provided with the Cnap monitor. All of these devices were attached to a Bipoac MP150 amplifier, which was linked to a third computer recording these responses using Acqknowledge version 4.1.

3.4 Procedure

After consenting to take part in the study, participants completed the STAI and provided information on their driving behaviour.The physiological equipment was then placed on the participant’s non-writing hand and arm, before eye tracking calibration took place. Participants were then told that they would be watching a series of driving clips, all taken from the driver’s point of view. They were to watch the videos as if they were the driver of the car, and as best as possible give a continuous rating, using their writing hand, of how much fear they would feel if they were the driver in the situation, using the variable response transducer provided to them. The scale ranged from 0 to 9, with 0 indicating that no fear would be felt and 9 indicating the maximum amount of perceived fear. The scale started at 0 for the start of each clip to control for starting position on the transducer. After practising looking at the screen and moving the transducer scale at the same time, the task then took place; this lasted approximately 15 minutes, after which equipment was removed, debriefing took place and an inconvenience allowance was provided.

4. Results

Descriptive statistics for physiological data and transducer responses were obtained in Acqknowledge before being copied and pasted into an Acqknolwedge journal. Excel was then used to uncounterbalance and average data across clips and windows. Eye movement data were extracted from iViewX into an iViewX Events file. Using a script created in MATLAB R2012, this file was parsed into its appropriate measurement windows and uncounterbalanced, before inputting into SPSS for analysis. Then, this was entered into IBM SPSS Statistics 21 to conduct a series of 3x3 (clip type x measurement window) ANCOVAs. Trait anxiety was entered into analysis as a continuous covariate.

When reporting findings for all data apart from questionnaire scores, only within-subjects effects and interactions are reported (See Table Two), as trait anxiety had no significant effects on variables (all p's>.05). Partial eta squared is reported to measure effect size, and Greenhouse-Geisser corrections are applied where there have been violations of sphericity. Where there are significant effects, planned a priori contrasts compare safe to dangerous clips and hazardous to crash clips. These contrasts also compare measures taken before the event to during the event, and the precursor of the event to its outcome (see Fig. 1).

Table One: Descriptive statistics for all dependent variables, according to clip type and measurement window (standard deviations are presented in brackets.

		Safe			Hazardous			Crash		
	n	Control	Precursor	Outcome	Control	Precursor	Outcome	Control	Precursor	Outcome
Mean fear perception	57	0.88 (0.89)	1.24 (1.02)	1.97 (1.86)	0.79 (0.86)	2.35 (2.01)	2.47 (2.23)	1.66 (1.51)	3.75 (1.99)	7.76 (1.82)
Mean hazard perception score	57	0.66 (0.89)	0.15 (0.29)	0.94 (0.86)	0.81 (0.74)	1.6 (0.72)	1.69 (0.64)	1.00 (0.71)	1.01 (0.54)	1.02 (0.69)
Skin conductance (mS)	56	4.31 (2.12)	4.24 (2.12)	4.2 (2.13)	4.31 (2.17)	4.25 (2.15)	4.26 (2.15)	4.25 (2.15)	4.28 (2.19)	4.62 (2.27)
Heart rate (BPM)	55	76.72 (11.32)	75.82 (11.88)	75.14 (11.55)	76.89 (12.01)	75.47 (11.05)	75.12 (11)	76.05 (10.58)	74.38 (10.07)	74.52 (9.74)
Saccadic amplitude (degrees)	30	1.58 (0.79)	1.36 (1.15)	1.12 (0.54)	1.48 (0.69)	1.31 (0.71)	1.71 (0.71)	1.79 (0.93)	1.07 (1.14)	2.09 (0.92)

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Table Two: *F* values of main effects and interactions for all dependent variables (degrees of freedom are presented in parentheses).

	Clip Type (*F*)	Measurement Window (*F*)	Clip Type*measurement window (*F*)
Mean fear perception	307.9 (1.6,88.01)**	238.4 (2,110)**	81.52 (2.97,163.4)**
Mean hazard perception score	76.36 (2,110)**	13.28 (2,110)**	20.73 (3.36, 184.7)**
Skin conductance	19.93 (2,108)**	17.78 (1.32,71.18)**	48.51 (1.54, 83.36)**
Heart rate	2.99 (1.48, 78.25)	16.24 (2, 106)**	.71 (3.38, 179.1)
Saccadic amplitude	3.39 (2, 56)*	12.95 (1.45, 40.52)**	12.61 (3.05, 85.34)**

**p*<.05; ***p*<.001

4.1 Mean perceptions of fear and hazard perception scores

Table Two shows that significant main effects of clip type and measurement window were found, along with a significant interaction. Higher fear ratings were found in dangerous clips than safe clips ($p<.001$, $\eta_p^2=.899$), and there were higher fear ratings in crash clips compared to hazardous clips ($p<.001$, $\eta_p^2=.818$). Higher ratings were also found in event windows compared to control windows ($p<.001$, $\eta_p^2=.882$), and also during outcome windows compared to precursor windows ($p<.001$, $\eta_p^2=.687$). The interaction suggests that the difference in mean response in the control window compared to the event windows was smaller in safe clips (m difference= 0.73) than in dangerous clips (m difference= 3.66, $p<.0001$, $\eta_p^2=.829$), and the difference between the precursor and outcome windows was also smaller for safe clips (m difference= 0.73) than for dangerous clips (m difference= 2.12, $p<.0001$, $\eta_p^2=.235$). Comparing hazardous to crash clips, smaller differences are found between the control and event windows for hazardous clips (m difference= 0.12) than for

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crash clips (m difference= .4, $p<.0001$, $\eta_p^2=.54$), and the difference between the precursor and outcome window was also smaller for hazardous (m difference= 0.12) than for crash clips (m difference= 4, $p<.0001$, $\eta_p^2=.71$).

Significant main effects and interactions were also found for calculated hazard perception scores. Reaction times were converted into hazard perception scores by splitting each individual window into five equal time segments, and giving participants scores of 5, 4, 3, 2, 1 or 0 depending on which time segment they had responded in (see Fig.1 for a full description). Scores were significantly higher in dangerous clips than safe clips ($p<.001$, $\eta_p^2=.765$), but higher in hazardous clips compared to crash clips ($p<.001$, $\eta_p^2=.209$). When comparing windows, higher scores were found in event windows compared to control ($p=.001$, $\eta_p^2=.186$). Contrasts on the interaction found that the difference in scores between the control and event windows was smaller for safe clips (m difference= 0.11) than for dangerous clips (m difference= 0.85, $p<.0001$, $\eta_p^2=.375$), but the difference in scores between the precursor and outcome windows was larger in safe clips (m difference= 0.8) than for dangerous clips (m difference= 0.09, $p<.0001$, $\eta_p^2=.339$). Comparing hazardous to crash clips, differences in score in the control window compared to the event was larger for hazardous (m difference= 0.84) than for accident (m difference= 0.01, $p<.0001$, $\eta_p^2=.395$).

To summarise, average fear responses to clips increase according to level of clip arousal, and its interaction with measurement windows indicates an increasing difference between windows with increasing levels of clip type. However, when comparing hazardous to crash clips, it seems that there are greater changes in response to precursor windows compared to before or afterwards; in particular, people are faster at responding during these windows whilst watching hazardous clips, as indicated by higher hazard perception scores (See Table One).

4.2 Physiological measures

4.2.1 Skin Conductance

Data was initially smoothed according to recommendations by Kim et al. (Kim, Bang & Kim, 2004). Due to an inability to record reliable skin conductance, data from one participant was excluded, meaning data from 56 participants was analysed.

Significant main effects and of clip type and window were found for skin conductance measures, as well as a significant interaction (see Table Two). Lower skin conductance was found in safe clips compared to dangerous clips ($p<.001$, $\eta_p^2=.223$), and skin conductance was also lower for hazardous compared to crash clips ($p<.001$, $\eta_p^2=.316$). Skin conductance was also lower during precursor windows than outcome windows ($p<.001$, $\eta_p^2=.376$).

Contrasts on the interaction showed that differences in the control window compared to events were greater for safe clips (m difference = -0.095 mS) than for dangerous clips (m difference = 0.049 mS, $p<.0001$, $\eta_p^2=.466$). However, the difference in mean skin conductance between precursor and outcome windows was smaller for safe clips (m difference = -0.03mS) than for dangerous clips (m difference = 0.18 mS, $p<.0001$, $\eta_p^2=.448$). When comparing hazardous clips to crash clips, differences between the control window and event windows were smaller overall for hazardous clips (m difference= -0.051 mS) than for crash clips (m difference= 0.2 mS, $p<.0001$, $\eta_p^2=.525$). Differences between the precursor and outcome windows were also smaller for hazardous clips (m difference= 0.009 mS) than for crash clips (m difference = 0.34 mS, $p<.0001$, $\eta_p^2=.467$).

Thus there was an overall increase in mean skin conductance according to measurement windows and clip arousal. However, there is a decrease in skin conductance in safe clips only; where hazardous and crash clips are concerned, there is a smaller increase made from precursor window to afterwards for hazardous clips compared to crash clips (See Table One).

4.2.2 Heart Rate

Two sets of data had to be discarded from heart rate analysis, leaving a total of 55 datasets input into analysis. Only a significant main effect of measurement window was found (See Table Two). Contrasts found that heart rate was significantly greater in control windows than in event windows ($p<.0001$, $\eta_p^2=.394$) (See Table One).

4.3 Saccadic Amplitude

Due to hardware problems, there were a variety of issues with recording reliable saccadic amplitude data; after close visual inspection, it was decided that data from 27 participants needed to be excluded, leaving 30 sets of data in the final analysis.

Significant main effects of clip type and measurement window were found, as well as a significant interaction. Saccadic amplitude was smaller during safe clips than dangerous clips (p=.01, $\eta_p^2=.214$), and with regards to measurement windows, amplitudes were greater in control than event windows (p=.015, $\eta_p^2=.193$), but smaller during precursor windows than outcome windows ($p<.001$, $\eta_p^2=.382$).

Contrasts on the interaction suggested that the difference in amplitude in control windows compared to event windows was greater for safe clips (m difference=.033) than for dangerous clips (m difference= 0.1, p=.013, η_p^2=.201). The difference in amplitude between precursor and outcome windows was smaller for safe clips (m difference= 0.24) than for dangerous clips (m difference= -0.71, p<.001, η_p^2=.465). However, when comparing hazards to crashes, differences in amplitude between precursor and outcome windows were smaller for hazards (m difference= -0.4) than for crashes (m difference= -1.02, p=.01, η_p^2=.214).

Therefore, smaller saccadic amplitudes were found for safe clips compared to dangerous clips, and an overall decrease in saccadic amplitude was found across windows. When observing dangerous clips, both seem to follow a non-inverted 'U' shaped pattern of amplitude across time. However, this is to a smaller degree in hazardous than crash clips (See Table One).

5. Discussion

5.1 Findings

In this study, it was hypothesised that increased levels of fear would be felt with increasing levels of arousal within driving clips, and that this hypothesis would be reflected by physiological and behavioural variables, thus reflecting fear as a function of bottom-up, environmental influences. It was also predicted that trait anxiety differences could interact with these fear responses, due to the additional influence of top-down resources. Analysis of the data suggests that whilst there is support for the initial hypothesis, these findings are seemingly independent of trait anxiety levels.

Firstly, mean perception of fear increased across time and according to type of clip. If we accept that fear as an emotion is a correlate of risk perception (Schmidt-Daffy, 2013), then it not only suggests that the chosen manipulation method was suitable, but also the possibility that fear correlates with risk on a wide range of environmental influences of threat. In dangerous driving clips, mean skin conductance increased overall across time, albeit to a much greater degree in crash clips. The fact that it increased in a relatively similar pattern to mean fear perception could indicate that the skin responses were a reaction to the increased fear felt whilst watching the videos. It is acknowledged that skin conductance is sometimes seen as a measures that only reflects non-specific general arousal (Fuller, 2005), and this could also explain the result. Nonetheless, this provides evidence supporting the notion that general threat increases physiological reactivity (Tomaka et al., 1993; Palomba et al., 2000), and adds to it by suggesting that it can occur when viewing dynamic as well as static stimuli. The similarities between the two variables could also indicate that skin conductance may be acting as a somatic marker that guides the perception of fear (Damasio, 1996); this inference supports similar driving research (Kinnear, Kelly, Stradling & Thomson, 2013), and it would be interesting to see if this pattern is found in future studies..

A ‘U’ shaped pattern of saccadic amplitude was also found in dangerous clips, which would provide support for the notion of cognitive tunnelling within dangerous driving situations (Chapman & Underwood, 1998). However, this was to a much lesser degree in hazardous compared to crash clips. It is possible that sources of threat were more quickly recognised in hazardous clips, as indicated by higher hazard perception scores; as a result of this faster detection, participants may have been searching the environment surrounding the source of threat in hazardous clips to ensure that no other dangers were evident (Kimble et al., 2014), which in turn would control any negative emotions such as anxiety (Adenauer et al., 2010).

Additional evidence that could support this theory comes from the heart rate findings, where average heart rate was found to be significantly greater in control windows than event windows. This could be seen as evidence of heart rate deceleration; this deceleration has been suggested as evidence of an orienting response (Bradley, Codispoti, Cuthbert & Lang, 2001), which in turn can heighten attention and increase the intake of information. In driving research, this orienting response could be advantageous, as it has been associated with an increased need to take in visual information on the road (Backs, Lenneman, Wetzel & Green, 2003). Thus the fact that evidence was found for deceleration in the present study could indicate that there was a greater need to take in visual information in order to deal with a potentially threatening situation. However, it is acknowledged that differences between types of clip did not reach significance; therefore it is difficult to explain why deceleration would have also been found in safe clips, when no threatening events were occurring.

It is also worth noting that calculated hazard perception scores were fairly low overall. Whilst they have been used in previous research, it is once again highlighted that if participants were taking genuine hazard perception tests and gaining the average score for each clip, then nobody would pass the test (Jones, Chapman & Bailey, 2014). This probably reflects the fact that participants taking a real hazard perception test have very specific expectations about what types of hazard they are looking for. In the current research some clips contain no hazards at all, while others contain actual crashes. This is possibly more representative of the range of real driving situations and highlights the possibility that hazard perception in real driving situations may be harder than when it is encountered in a formal test environment. The relatively low scores in precursor windows compared to control and outcome videos is likely to simply reflect the fact that these windows are shorter, and the uneventful videos provide a baseline condition that allows us to estimate the size of this effect.

5.2 Implications and recommendations for future research

Taking these findings together, we suggest that these results could have interesting implications with regards to training. One possible reason for differences in reactions between hazardous and crash clips is that some of the vehicles that subsequently caused crashes came from unusual locations. As can be seen in ‘Appendix A’, whilst sources of hazards typically emerged from more predictable locations such as other junctions and the side of the road, crashes occurred as a result of vehicles emerging from less expected locations such as the same side of the road or driving across lanes. Therefore it might be beneficial to train drivers to be able to more efficiently locate sources of threat that emerge from less obvious places in the driving environment. This could be achieved using PC-based training. In previous research, this has been shown to beneficially change glance behaviour in hazardous situations for more experienced drivers (Petzoldt et al., 2013; Pradhan, Pollatsek, Knodler & Fisher, 2009). It would be interesting for future research to investigate whether such training does have an impact on gaze behaviour and reaction times in more dangerous situations. Furthermore, it would be interesting to see if this training did result in changes in fear perception and physiological reactions, in such a way that observing crash clips could be seen as comparable to hazardous clips.

There are two other recommendations for future research that can be made from this study, and both highlight the increased need for simulator research within the field. Firstly, trait anxiety levels did not interact with increasing levels of clip arousal, as was predicted. One thing to consider is that the majority of research into trait anxiety and driving has been conducted using questionnaires or self-report data. Whilst these have provided interesting findings that suggest drivers with high trait anxiety may be more dangerous (Pourabdian & Azmoon, 2013; Shahar, 2009; Dula et al., 2010), this may not detect all manifestations of anxiety (Taylor & Sullman, 2009), nor may it necessarily reflect actual on-road behaviours. This makes the current study unique in that it goes beyond simple self-report behaviours in order to try and find differences according to trait anxiety. Though the dependent variables within this study were justified, it may be that trait anxiety has more influence on behaviours than physiological or attentional variables, at least in the context of driving. Simulator research should attempt to discover this in future research. Alternatively, it may be interesting to see if trait interacts with state anxiety in simulator research; the majority of research has found significant changes in driving behaviour as a function of state anxiety (Briggs, Hole & Land, 2011; Morton & White, 2013; Wilson et al., 2006), and it is possible that trait anxiety may have an effect on this.

Secondly, with regard to levels of clip arousal, one influence of arousal that wasn't considered was the characteristics of the driving environment itself. For example, on-street parking can increase feelings of tension and reduce perceptions of safe speed (Chinn & Elliott, 2002a), and also increase workload, reduce actual speeds and increase reaction times to peripheral cues and unexpected threats such as pedestrians (Edquist, Rudin-Brown & Lenne, 2012). Consequently, it is acknowledged that the feature of buildings and built-up traffic in some of the clips in this study could have had a subsequent influence on the levels of fear experienced, rather than the events of the clip itself. Thus if this type of research is conducted in driving simulators, then future studies may need to consider controlling environmental characteristics, which may be easier within a simulated environment.

5.3 Limitations

However, there are some limitations in this study with regard to sample size. Firstly, it is possible that whilst the study was powerful enough to detect differences for within-subjects variables, the sample size may not have been large enough to detect moderate differences between trait anxiety groups. Post-hoc observed power analysis indicates a between-subjects power of .51 to detect medium effects sizes and an observed power of .97 to detect interactions between anxiety groups and the within-subjects variables. Thus although we can conclude strongly that the pattern of within-subjects results did not differ between the three anxiety groups ,we cannot be sure that overall levels of fear perception and associated physiological reactions did not differ between the three groups. In fact the average observed effect size due to anxiety in the current study was a Cohen's f of 0.1 (a value of 0.1 is generally described as a small effect). For between groups comparisons to be significant if this is an accurate estimate of the true effect size we would need to have tested 273 participants to achieve a power of 0.8 in the design. Therefore future research investigating this issue and using a similar paradigm should use a larger sample size to test for pure between-subjects differences.

A second limitation is that our sample primarily consisted of young females either studying or working within a University environment. It is acknowledged that younger drivers can be seen as more likely to engage in risky driving behaviours (Scott-Parker et al., 2014) or be less likely to self-regulate driving behaviours (Gwyther & Holland, 2012). Simultaneously, previous research suggests that women often express a more anxious style of driving (Gwyther & Holland, 2012; Mesken et al., 2007). In the present study, males had an average trait anxiety score of 33.4, whereas the average score for females was 39.5. This highlights the issue that a more representative sample may be needed in future research, both in terms of gender and age, and whilst several studies use samples that consist primarily of students, future driving research should observe those from more representative educational backgrounds..

5.4 Conclusions

Overall, the findings from this study suggest that fear, measured as a function of environmental arousal, can have a significant effect on physiological, attentional and behavioural responses. Some of these, such as skin conductance, could act as a somatic marker for subsequent feelings of fear, whilst others such as eye movements and standardised reaction times suggest more advantageous performance in some dangerous driving situations than others. These results could be important for the application of training programs that help drivers learn to anticipate sources of danger from a wider range of locations within the driving environment. Whilst trait anxiety did not impact dependent variables, this does not mean that it does not have an impact on driving behaviour, or that it is not separable from fear. It is likely that future research needs to look at this within more immersive paradigms such as driving simulators, and test a large range of people in order to assess how exactly anxiety, either in state or trait form, impacts driving within different fear-inducing contexts.

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Appendix ‘A’: Table of Clip Descriptions and Window Durations (in seconds)

Clip Number	Clip Type	Duration of Control Window (seconds)	Duration of Precursor Window (seconds)	Duration of Outcome Window (seconds)	Description of the clip
1	Uneventful	24.96	10.4	16.64	Residential UK area, one lane in each direction. Participant’s car is following the land rover ahead throughout.
2	Uneventful	13.2	3.16	12.32	Residential UK area. Goes over speedbumps before turning right at junction. Continues driving straight ahead until the end of the clip.
3	Uneventful	24.96	10.4	16.64	Non-UK country road, one lane in each direction. Participant’s car is following the car ahead throughout.
4	Uneventful	13.2	3.16	12.32	Residential UK area. Cars are parked on either side, but no traffic approaching as participant’s car drives throughout the clip.
5	Uneventful	24.96	10.4	16.64	Urban UK area, two lanes in each direction. Participant’s car stops at red traffic lights but then carries on driving.
6	Uneventful	13.2	13.16	12.32	Residential UK area, one lane in each direction. Participant’s car follows the car ahead.
7	Hazardous	28.2	14	9.8	Residential UK area, cars parked on either side of road. In precursor window, pedestrian crosses the road, gets into car and pulls out in front of participant’s car. Both cars then continue to drive until the end of the clip.
8	Hazardous	29.96	2.24	19.8	Residential UK area. In precursor window, pedestrian crosses the road from behind

					a van. Participant’s car then continues to drive until the clip ends.
9	Hazardous	8.8	9.36	33.84	Residential UK area. Pedestrian runs out into the road. Participant’s car then continues driving until the end of the clip.
10	Hazardous	9.24	5.72	37.04	Residential UK area. A group of pedestrians cross a zebra crossing. Participant’s car then continues driving until the end of the clip.
11	Hazardous	15	5.04	31.96	UK country road. A van pulls out from a junction on the left. Participant’s car then continues driving until the end of the clip.
12	Hazardous	8.08	12	31.92	UK A-road. A lorry crosses the central reservation to join participant’s side of the road. Participant’s car then continues driving until the end of the clip.
13	Crash	11.36	3.84	23.8	Non-UK based urban area. Car drives across lanes, crashing into participant’s car and causing it to flip over. Clip ends on smashed windscreen.
14	Crash	12.76	2.08	8.16	Non-UK based urban area. Participant’s car crosses roundabout and a car from the other side of the road swerves and crashes into participant. Clip ends with participant’s car on its side and windscreen wipers moving.
15	Crash	11.4	2.44	12.16	Non-UK based urban area. In stationary traffic, participant’s car crawls until it reaches a red light. Land rover from the opposite side of the road is hit by another car, causing it to tip on its side and swerve into participant’s car. The clip ends with both cars stationary.
16	Crash	14.32	1.52	14.16	Non-UK based country road, one lane in each direction. Car in the opposite lane swerves and crashes into participant’s car, causing the participant’s car to fall into the side of the road and crash into trees. Clip ends with the participant’s car facing the forestry.
17	Crash	20	2.52	10.48	Non-UK based country road, snowing, one lane in each direction. Participant’s car

					tries to overtake but crashes into a lorry. Ends with a close-up shot of the smashed windscreen.
18	Crash	7.84	5.96	7.2	Non-UK based country road, two lanes in each direction, night-time. Collision with a car travelling in the opposite direction. Clip ends on the smashed windscreen of the participant’s car.